application of kerosene and fish oil. Subsequently Mr. Maskell, dealing with the *two* species, says that a mixture of kerosene and linseed oil (one-third or one-fourth of the former) as recommended by Mr. Comstock in America, had been perfectly successful so far as regards the *Mytilaspis*, which he does not regard as serious in its probable effect upon wattles (*Acacia*), but very serious with respect to fruit and other trees. On the other hand, he considers all remedies useless against the *Iceryа* of the wattle other than the radical one of cutting down and destroying the affected trees. No indication is given, however, of the use of a force-pump in distributing the kerosene; if this were used, the remedial agent might be distributed to a greater height than would be possible by mere hand application, and moreover it might be made to penetrate dense hedges, &c., the interior of which it would be impossible to drench by hand labour. The improved form of application, as a "kerosene emulsion," recommended by Prof. Riley and Mr. Hubbard, did not appear to be known in New Zealand at the time the Report was drawn up. Any way it is satisfactory to hear that the *judicious* application of kerosene will certainly destroy scale insects without necessarily damaging the plants.

THE same Report speaks very hopefully of the ultimate success of attempts to cultivate hops in the province of Wellington; in Nelson success has been already secured. The great drawback is the expense of providing the necessary *poles*, and much stress is laid upon the necessity for cultivating oak, ash, birch, and species of *Eucalyptus* for that purpose. Of the indigenous poles, those of *Myrsine urvillei* are said to be the most durable.

THE additions to the Zoological Society's Gardens during the past week include a Toque Monkey (*Macacus pileatus* ♀) from Ceylon, presented by Mr. J. H. Barker; a Macaque Monkey (*Macacus cynomolgus* ♂) from India, presented by Mr. Douglas; a Common Marmoset (*Hapale jacchus*) from Brazil, presented by Mrs. Archer; a Moorhen (*Gallinula chloropus*), British, presented by Mr. T. E. Gunn; a Gannet (*Sula bassana*), British, presented by Mr. J. C. Baxter; two St. Thomas's Conures (*Conurus xantholæmas*) from St. Thomas, West Indies, presented by Mr. C. Wallis Enslie; two Fringed-lipped Lampreys (*Petromyzon branchialis*), British, presented by the Rev. F. T. Wethered; a Pied Wagtail (*Motacilla lugubris*), British; a Slaty Egret (*Ardea gularis*), European, purchased.

INTERNATIONAL POLAR OBSERVATORIES

I BEG to inclose you an extract from a letter just received from Prof. Wild, President of the International Polar Committee, and which gives information as to the several expeditions which conducted observations in the circumpolar regions during the twelve months ending August 31, 1883.

ROBERT H. SCOTT

"I take this opportunity of stating concisely what I have hitherto learnt as to the present condition or the return of the various expeditions.

"1. The United States—Point Barrow.—The Expedition was to have returned in the summer of 1883. Definite information as to its return has not yet been received.[1]

"2. England and Canada—Fort Rae, on the Great Slave Lake.—According to a communication received from Mr. Scott, dated November 21 last, the Expedition has safely returned to England.

"3. United States—Lady Franklin Bay.—The attempts to relieve the Expedition this summer by ship have, like those of last year, failed owing to the unfavourable condition of the ice. (Extract from newspapers.)

"4. Denmark—Godhavn, in Greenland.—According to a communication from Captain Hoffmeyer, dated December 8, the Expedition has safely returned to Copenhagen with a rich store of observations.

"5. Germany—Cumberland Sound (Davis Strait).—According to a communication received from Dr. Neumayer, dated November 1, the Expedition has safely returned to Hamburg, having completed its task in a satisfactory manner.

"6. Count Wilczek's Station (Austria)—Jan Mayen, in Marymuss Bay.—The Expedition has safely returned to Vienna, having completely carried out its programme. A short report of its operations has been published by M. von Wohlgemuth, the Chief of the Expedition.

"7. Sweden—Spitzbergen (Cape Thordsen, in the Ice Fjord).—Dr. Rubenson states that the Expedition has safely returned to Stockholm.

"8. Norway—Bossekop, near Alten.—From a letter from Prof. Mohn, dated September 7, the Expedition stopped work on August 31, having completely carried out its programme, and on September 17, according to a report in *Naturen* (October, 1883) it safely returned to Christiania.

"9. Finland—Sodankyla.—The Expedition completed its task for the first year, but, according to a communication from Prof. Lemström, dated August 5, the observations will be continued another year, as the Government of Finland has provided the funds for the purpose.

"10. Russia—Nova Zembla (Möller Bay).—The Expedition returned to St. Petersburg in October with a rich store of observations.

"11. Holland—The Kara Sea.—The Expedition could not reach its original place of destination, Port Dickson, but was surrounded by ice in the Kara Sea, and has, according to a letter from Prof. Buys Ballot, dated October 1, safely returned to Utrecht, having under the circumstances only imperfectly carried out its programme.

"12. Russia—Mouth of the Lena (Sagastyr).—The Expedition, which suffered from storms during the passage down the Lena, was not properly established until October 20, 1882; from that date it has been able to carry out all the work laid down in the programme. It will continue its observations for another winter.

"13. France—Cape Horn (Orange Bay, Terra del Fuego).—According to a report from Prof. Mascart, dated November 17, the Expedition has returned safely to Paris, with a rich store of materials.

"14. Germany—The Island of South Georgia (Moltke Harbour).—This Expedition has also safely returned, according to a communication from Dr. Neumayer.

"Of the fourteen Expeditions, therefore, three will continue their observations for about another year (Lady Franklin Bay, Sodankyla, and Lena delta); the continuance of a fourth (Point Barrow) is at present unknown, the other ten have safely returned."

[1] We believe this party arrived at San Francisco some weeks ago.—ED.

MOVEMENTS OF THE EARTH[1]

III.—*Rotation of the Earth*

THE several ideas concerning the movements of the earth which were introduced in the last lecture will in the present one have to be dealt with in greater detail.

It was then agreed that if the whole expanse of the heavens were to travel with a perfectly equable motion in one direction, such a motion for instance as would result from all the stars being fixed to a solid transparent substance like those crystal spheres that the ancients really believed to exist; or if, on the other hand, the earth herself, instead of being free to turn as she listed with varying velocity in any direction, really went with perfect constancy in the direction opposite to the apparent motion of the stars, the visible effects would be the same in both cases, so that an appeal to our eyes would not suffice to enable us to say whether the earth moved or whether she remained at rest while the celestial sphere revolved around her.

Under these circumstances what is to be done? It has been seen how, both with regard to the measurement of space and the measurement of time for astronomical purposes, those interested in the physics and beauties of the various classes of celestial bodies outside our own earth have picked and chosen now one bit of physical science and now another to help them in their inquiries; and with regard to this very important question, "Does the earth move or is she at rest?" we shall see how very beautifully and perfectly the question has been answered by the application of certain mechanical principles.

The majority of people, I suppose, have some acquaintance, however slight, with machinery—with steam engines for in-

[1] Continued from p. 69.

stance; and it is a familiar fact how very important a part is played in the steam-engine by the flywheel. Why should that be? Why should this flywheel be so important that it is only quite recently that mechanicians have learned to do without it? For this reason: if a mass of matter such as a flywheel is once made to revolve, it will retain that motion for a long time, resisting any tendency to an increase or decrease of its velocity. It is in consequence of this property which the revolving flywheel possesses that an engineer is able to get over the dead points in his engine, whilst

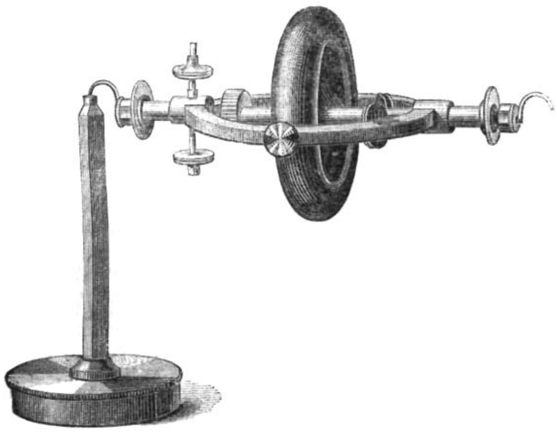

FIG. 27.—Rapidly rotating wheel supported at one end of its axis.

it also acts in preventing the engine making too sudden a start. In addition to this, when we have a mass of matter in the condition of the revolving flywheel it has some very peculiar qualities, only observed when such a mass of matter is in motion. If, then, we have a wheel so arranged that a very rapid rotation is being imparted to it, it does not behave as it would when at rest. These properties possessed by a rotating body can be well shown by an instrument known as the gyroscope, of which we shall speak more fully later on. It consists essentially of a

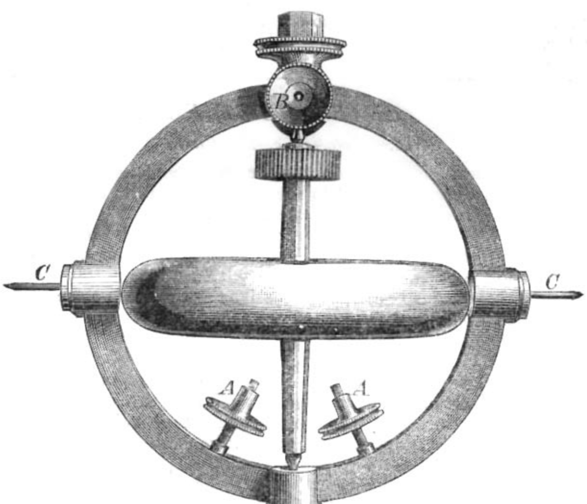

FIG. 28.—Rotating disk of gyroscope. C C, knife edges; A A, B B, adjusting weights.

disk to which a very rapid rotation can be imparted by a train of wheels or by other means. If the disk be set rotating, it is found to possess those curious qualities of which I have spoken. If whilst rotating at a high velocity it be placed in the position shown in Fig. 27, it will not fall, but will take on a movement of revolution round the stand.

From considerations suggested by this and other similar experiments, Foucault pointed out that it might be demonstrated whether the earth moved or whether she remained at rest. It struck him that the problem should be attacked somewhat in this manner:—

Suppose the earth to be at rest, and that either at the north or south pole a pendulum, suspended so that its point of support had as little connection with the earth as possible—so that it should, in fact, like the rotating flywheel, be independent of external influences, were set vibrating. Then an observer at the north or south pole would note that the swinging pendulum (the earth being considered as at rest) always had the same relation to the objects on his horizon. But, said Foucault, suppose that the earth does move. Then the swing of such a pendulum would not always be the same with regard to the places on the observer's horizon. Let the earth be represented by a globe. Suppose it to rotate from west to east. Place it with the north pole uppermost, and set the pendulum, whose point of support is disconnected from the rotating earth, vibrating. Then the pendulum will appear to travel from left to right as the earth rotates from right to left beneath it. Now suppose the pendulum to be suspended in the same way at the south pole, right and left now being changed. The earth of course rotates in the same direction as before, but the pendulum now appears to change the

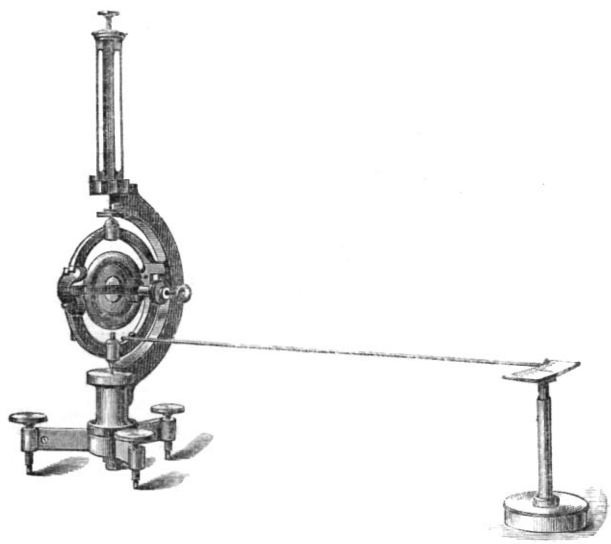

FIG. 29.—Gyroscope; general view.

plane of its swing from right to left. At the equator the earth simply rotates straight up and straight down beneath the swinging pendulum.

From these considerations it became evident to Foucault that, if there were any possibility of demonstrating the movement of the earth by means of the pendulum, the demonstration would take this form. Provided it were possible to swing a pendulum so that it should be as free as possible from any influence due to the rotation of the earth, and take that pendulum to the north pole, it would appear to make a complete swing round the earth in exactly the same time that it really takes the earth to make a complete rotation beneath it. At the south pole exactly the same thing would happen except that the surface of the earth would appear to move in the opposite direction to what it did at the north pole. Now it will be perfectly clear that if we thus get a pendulum appearing to swing one way on account of the true motion of the earth at the north pole and in the opposite direction on account of the true motion of the earth at the south pole; at the equator, as we found in dealing with our model earth and model pendulum, it will not change the plane of swing either way, that is to say, the time taken by a pendulum to make a complete swing will be the smallest possible at the poles, whilst at the equator it will be infinite.

At all places, therefore, between either pole and the equator

the period of swing will be different, and the time taken to make a complete swing will increase or decrease as the equator is approached or receded from. So much for theoretical considerations. Can they be put to the test of experiment, and an answer obtained from nature herself? The fact is that this idea of Foucault's is so beautifully simple that anybody can make the experiment providing he has the means of using a very long pendulum. This pendulum must be rigidly, but at the same time very independently, supported.

Beneath the pendulum, in contact with the earth, and therefore showing any movement of rotation which the latter may possess, is a board, on the centre of which the pendulum nearly rests. From the central point of this board lines are described showing so many degrees from the central line over which the pendulum bob swings. These preliminaries being arranged, let the pendulum be started. This is done by drawing it out of the vertical and tying it by a thread which is burnt when it is desired to start the experiment.

Then, in consequence of that quality the existence of which was revealed to us by the rotating disk and which is possessed by this vibrating pendulum, and in consequence of the precautions which have been taken to prevent its swing being interfered with by the motion of the earth or other perturbing influences, it should be found, if Foucault's assumption be correct, that the earth is moving beneath the pendulum. And if all the conditions of the experiment have been complied with it is found that the pendulum moves over the scale as the earth rotates beneath it. That then is one demonstration of the existence of the earth's rotation.

The question now arises whether there be any other method of determining the same thing. There is, but in answering the question in the affirmative it must be said that this second method is neither so simple nor so satisfactory as the first.

We owe it also to the genius of this same man, Foucault. It depends upon the same principles and is connected with the same series of facts as the other. But before proceeding to

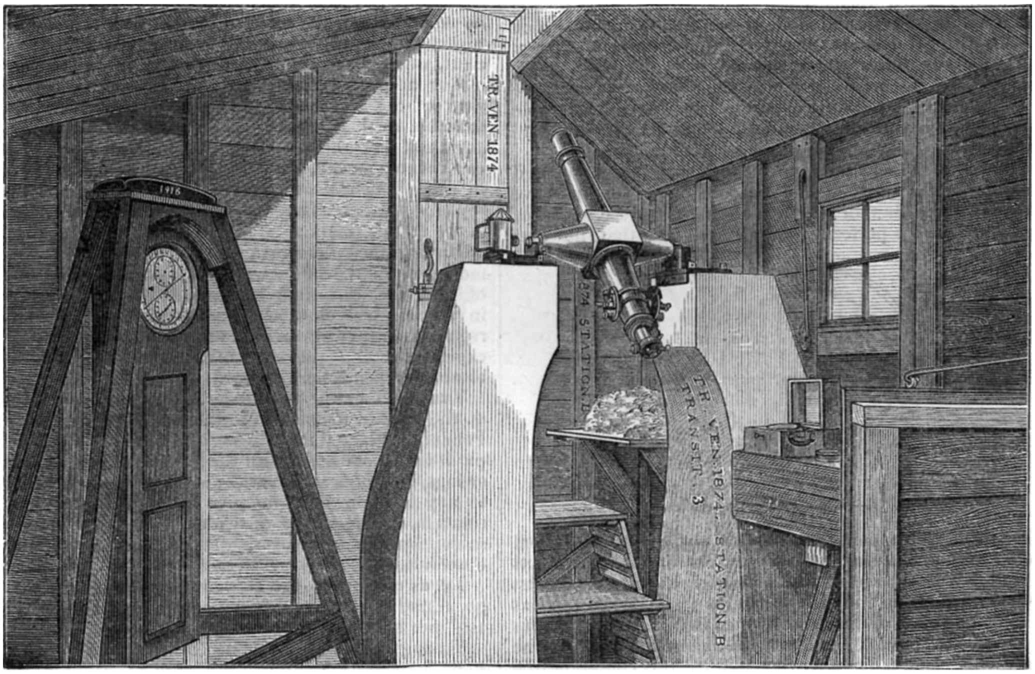

FIG. 30.—Transit instrument and clock.

discuss this second experiment it will be well to consider these two tables, which have been taken from Galbraith and Haughton's "Astronomy," because they show not only what the swinging pendulum should do if it behaves properly, but also what the gyroscope, the instrument used in the second experiment, should do if it behaves properly.

The first table is called

Hourly Motion of Pendulum Plane.

Place	North Lat.	Observed motion per hour	Calculated motion per hour	Observer
Ceylon	6° 56′	1°·870	1°·815	Schaw and Lamprey.
New York	40 44	9·733	9·814	Loomis.
Providence, R.I.	40 49½	9·955	9·833	Carswell and Norton.
New Haven, Ct.	41 18½	9·970	9·929	
Geneva	46 12	10·522	10·856	Dufour and Wartman.
Paris	48 50	11·500	11·323	Foucault.
Bristol	51 27	11·788	11·763	Bunt.
Dublin	53 20	11·915	12·065	Galbraith and Houghton.
Aberdeen	57 9	12·700	12·636	Gerard.

The second is

Rotation of Earth deduced from Pendulum.

Place	Time of Rotation		
	h.	m.	s.
Colombo, Ceylon	23	14	20
New York	24	8	9
Providence, R.I.	23	38	29
New Haven, Ct.	23	50	7
Geneva	24	41	39
Paris	23	33	57
Bristol	23	53	2
Dublin	24	14	7
Aberdeen	23	48	49
Mean value	23	53	0

The pendulum plane is of course the plane in which the pendulum swings. The first column in Table I gives the place where the pendulum was set swinging, the second the latitude,

the third the observed motion per hour, and the fourth the calculated motion. The table has been so drawn up that it begins with places nearest the earth's equator and passes gradually to others further away, going from Ceylon at 6° N. lat. to New York at 40° N. lat., New Haven at 41°, and ending with Aberdeen at 57°. At the first-named place it will be seen that the pendulum swings through less than 2° per hour, whilst at Aberdeen it swings through nearly 13°, which is an approximation, at least, to the statement I have made, that, since the rotation of the pendulum plane will be most rapid at either pole, the further from the equator we swing it the greater will be the number of degrees passed over per hour.

To turn now to the gyroscope. We shall expect, if we succeed in imparting to it a rotation which is independent of and unaffected by the earth's rotation, that the angular change shown by it will be the same as that indicated by the pendulum, or, in other words, that the number of degrees passed over will be the same in both cases.

In the gyroscope, that portion which corresponds to the swinging part of the pendulum is the heavy disk seen in Fig. 28, to which a very rapid rotation can be imparted. This disk is mounted upon the horizontal circle shown in the figure, which circle in its turn is mounted in a vertical one suspended by a bundle of raw silk fibres which depend from the little screw shown at the top, by means of which the whole system can be raised, so preventing the vertical circle from resting its whole weight upon the pivot below, the use of which is not so much to support the apparatus as to guide it in its movements.

Now in order that the rotation of the disk shall be uninfluenced by the motion of the earth a great number of precautions have to be taken. The first of these is to insure that the whole of the apparatus shall be perfectly free to rotate, and that, however

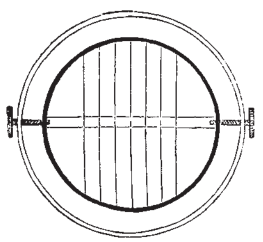

FIG. 31.—Wires in transit eyepiece.

much the silk fibres supporting the vertical circle may be screwed up in order that it may not rest its weight upon the pivot, its motion shall not be interfered with—that there shall be no twist in the thread. This is the first precaution; and, when this has been done, a condition of things is obtained in which the apparatus is perfectly free to move round a vertical axis represented by the silk fibres prolonged. Then, having fulfilled this condition, the next matter of importance is to see that the disk is perfectly free to move on the horizontal axis. For this purpose the wheel which holds the two extremities of the axis of the rotating disk is armed with counterpoise weights (see Fig. 28), two in a horizontal plane, A A, and two in a vertical plane, of which one is seen at B.

Then the knife edges, C C, which are exactly in the plane of the centre of motion of the whole system, are made to rest on two steel plates mounted on a separate stand, in order to ascertain if the moving parts are perfectly balanced, the perfection of balance being determined by the slowness with which it oscillates up and down. But this is not all; it must not only be so adjusted by these weights, A A, that the ring shall remain horizontal, but it must be so perfectly balanced by the two weights, one of which is seen at B in Fig. 28, that if a considerable inclination be made from the horizontal it will be taken up equally on both sides. Finally, the instrument must be so adjusted that when the two delicate knife edges are placed on the two steel plates in the outer ring (see Fig. 28) the ring carrying the disk shall be perfectly free to move and have its centre of motion exactly identical with the centre of motion of the outer ring and of the disk itself. Then, when all these precautions have been taken, and the disk is set rotating with considerable velocity by means of a multiplying wheelwork train, we have, as far as the mechanics of the thing are concerned, an experiment just like the other, with this important difference, however, that, whereas the pendulum experiment always succeeds, much trouble is often experienced in experimenting with the gyroscope. But, when the multiplicity of the conditions necessary to the success of the experiment is considered, this is not surprising. If, however, all the conditions have been adhered to, the pointer with which the instrument is fitted (see Fig. 29) ought to move over the scale at exactly the same rate that the pendulum moves over the scale beneath it. But even supposing that the pointer of the gyroscope does move over the paper and in the right direction when the apparatus rotates one way, this is not enough. The demonstration of the validity of the result given by it is that an equivalent deviation is obtained when the apparatus is turned about in every possible direction. The first test of course is to rotate in the opposite way, then, if all the adjustments have been properly made, the deviation obtained will be the same in amount and direction as before, and it may be taken that the result obtained is then really due to the earth's rotation.

With this reference to the most important points connected with the gyroscope, we may bring our inquiries under this head to a close. So many men have worked with the instrument in so many lands, and under such rigid conditions, that there can be no doubt that the rotation of the earth is demonstrable by it, although certainly its verdict is not anything like so sharp, or so clear, or so easily obtained, as that given by the pendulum.

Our appeal to physics has at once put out of court the old view of the arrangement of the universe, which placed an immovable earth at its centre. How Copernicus was the first to point out that this old view was incorrect, and that it was the earth which moved, and how Galileo was persecuted because he, in times much less fortunate than our own, had the courage to say so,—these are familiar points in the history of the discovery of the earth's rotation.

Having then demonstrated the existence of this particular movement of the earth, we must now proceed to a consideration of the rate, direction, and results of the movement,—connect in fact the pendulum of Foucault with that of Huyghens, and regard the physical pendulum as giving an important use to the experiments of Galileo and of Huyghens in which they caused it to act as a controller of time.

Turn back to our two tables. They are not without interest at the present moment. In the first table, "Hourly Motion of Pendulum Plane," the observed motion of the pendulum plane per hour is connected with the latitude of the place at which it swings, varying as that varies; and therefore the observed motion in any latitude ought to give the same value for the earth's rotation, the closeness of which to the real value will at the same time be a measure of the accuracy of our pendulum observations.

Let us endeavour then to find out in what time the earth must go round in order that the pendulum plane may vary (say) $1\frac{8}{10}°$ per hour in Ceylon, $11\frac{1}{10}°$ in Dublin, and so forth.

Taking our clock as being divided into twelve hours, each hour into sixty minutes, and each of these again into sixty seconds, it is found (see Table 2) that the value for Ceylon is 23h. 14m. 20s., and for Dublin 24h. 14m. 7s., the mean value of the observations at the various places mentioned in the table being 23h. 53m., so that according to that table the earth rotates on its axis in a few minutes less than twenty-four hours.

Now although such an approximation to the real value may suffice for the great mass of mankind, it is not an astronomical way of dealing with the question. We have seen the circumference of a circle divided first into degrees, then into $\frac{1}{3}$ degrees, next into seconds, and finally into tenths of seconds; by the application of electrical principles, time has been even more finely divided, and the question naturally arises, Are there any means of determining the exact period of the earth's rotation?

There are means of doing this. In the last lecture occasion was taken to point out that the stars are infinitely removed from the earth; the stars being so infinitely distant, a slight change in their position will not be perceptible to an observer on the earth, and the place of a star to-day and its place to-morrow are the same so far as relates to any parallactic change of position.

This being premised, it will be clear that, in order to get out the exact period of the earth's rotation, one only has to make an observation of any star on one particular day (such observation being of course made with a clock), and repeat the observation when the star is in the same position on the succeeding day. The time which elapses between the observations must be the time taken by the earth to make a complete rotation. But it

will be asked, How are these observations made, and how is it known when the star *is* in the same position when the second observation is made?

For this purpose a transit instrument is used (see Fig. 30). This differs from an ordinary telescope, being so mounted as to move only up and down, and is armed not with simple cross wires, but with an odd number of parallel and equidistant vertical wires crossed by a single horizontal wire. It is also usually provided with a circle to give declination. If from any part of the earth an observation be made on any particular star on one day, and then another observation made on the same star when it is in the same position the next day, as has been said, the interval between the two observations must be the time taken by the earth to move round once.

By having such an arrangement as exists in the transit instrument, by which it can swing in the plane which coincides with the axis on which the earth turns, any star may be chosen for the observation. Suppose, for instance, the instrument be pointed to the north pole star, then, in consequence of the tremendous distance of the stars, the axis of the telescope is practically coincident with the axis of the earth. But suppose another star to be observed, it will be quite clear that we may make the observation on it, or any other star we choose. When the instrument is upright it points to the zenith. A star in the zenith may therefore be selected for the observation.

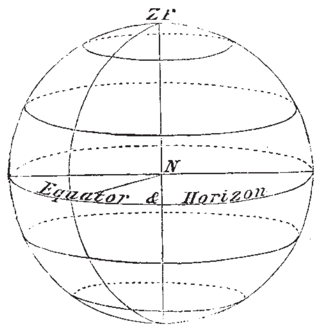

FIG. 32.—Showing that the true horizon of a pole is the equator.

It is observed when crossing the central wire of the instrument one day, and noted again when it crosses that wire on the succeeding day. But the observer does not limit his observation to the one central wire, in order to ascertain when the star is in the centre of the field. If he did so, he might miss his observation. That is why the simple cross wires have been replaced by a system of wires (see Fig. 31). As the star crosses the field of view, the observer, listening to the beats of the clock alongside, notes the time when it crosses each of the wires, and takes the mean of these observations, thus attaining to a much greater accuracy than if he had merely observed the transit over the central wire. With an ordinary clock it is found that a period, less by a few moments than twenty-four hours, elapses between two successive transits.

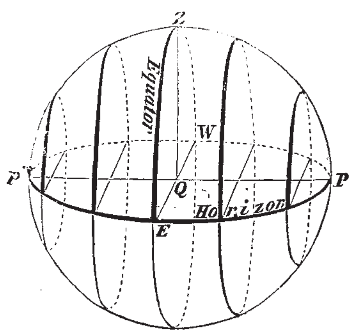

FIG. 33.—Showing that the poles lie in the horizon at the equator.

In order to get an absolutely perfect measure of time, the clock may be so rated that it should not be any indeterminate number of hours, minutes, and seconds, but twenty-four hours exactly between the two transits of that star. With a clock thus arranged, the time at which a star crossed the central wire of the transit instrument would really give a most perfect method of determining that star's place in the heavens, because, if the earth's rotation is an equable one and takes place in a period which we choose to call twenty-four hours, then two stars 180° apart will be observed twelve hours after one another, four stars 90° apart will be observed six hours apart, and so on; and clocks like this, regulated to this star time, exist in our observatories, being called sidereal clocks, because the time they give, which is not quite familiar to everybody, is called sidereal time.

Now let us consider our position on the earth with regard to the stars. This is a very interesting part of our subject, not only in its scientific aspect, but from the point of view of its usefulness, whether we wish to study the stars or define places on the earth's surface, the latter matter, however, being so intimately connected with astronomy proper that it is impossible to talk about the one without talking about the other.

Since we divide all circles into 360°, the circumference of the earth may be so divided, and the method in use of defining positions on the earth is to say of a place that its latitude is so much and its longitude is so much. Latitude begins at the equator with 0°, and terminates at the poles with 90°, being north latitude in the one case, and south latitude in the other. In the case of longitude, there is no such simple starting point, for whilst latitude is counted from the equator by everybody all over the world, longitude may commence at any point. In England we count longitude from the meridian of Greenwich. When the transit instrument at Greenwich is swept from the north point through the zenith to the south point it describes a half circle, which is called the meridian of Greenwich.

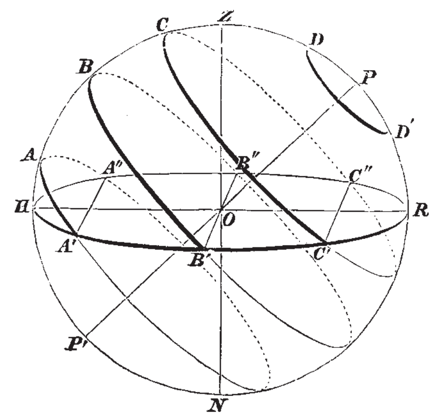

FIG. 34.—Horizon of a place in mid-latitude.

That is one point. Another point is this. Suppose the instrument to be set up not at Greenwich but at the north pole. Then the true horizon of the observer will be along the equator. Remove the instrument to the equator, and the true horizon will cut the poles. At a place in mid-latitude the true horizon would cut neither the pole nor the equator, but would be inclined to both (see Figs. 32, 33, and 34).

Then comes the important relationship between the latitude of the place and the altitude of the pole star above its horizon; that the number of degrees this star—be it north or south—is above the horizon of the observer will be the number of degrees of north or south latitude of the place where the observation is made. A place therefore in 10° N. lat. will (roughly) have the north pole star at a height of 10° above its horizon.

So much for this part of our subject. Let us now leave it, because, interesting as it is, it refers to a branch of astronomy with which at present we have less to do than with the more physical one; but it was well that we should pause for a few moments to note the tremendous importance to mankind of that particular movement of the earth which we have been considering.

J. NORMAN LOCKYER

(*To be continued.*)

PROBABLE NATURE OF THE INTERNAL SYMMETRY OF CRYSTALS[1]

THE theory of the modification of crystal angles, just offered in dealing with quartz, is manifestly applicable to all crystals not of the cubic system, and it is submitted that for every such

[1] Continued from p. 188.